Document No.c-3

Study Protocol

Land-based test

of

ECOMARINE Ballast Water Treatment System

March 28, 2011

Sumitomo Electric Industries, Ltd.

1. Test condition

Conduct the land-based test of the laboratory-scale ECOMARINE system developed by Sumitomo Electric Industries, Ltd. based on the standards for type approval test of ballast water treatment systems (established by the Inspection and Measurement Division of the Maritime Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, Japan)

2. Test facility

Name: Marine Technology Institute Corporation
Address: 2269-53, Seto-cho, Imari-shi, Saga, Japan

Set the laboratory-scale ECOMARINE system (treatment capacity: 200 m^3/h) on the shore and the test barge with the simulated ballast tanks on the sea.

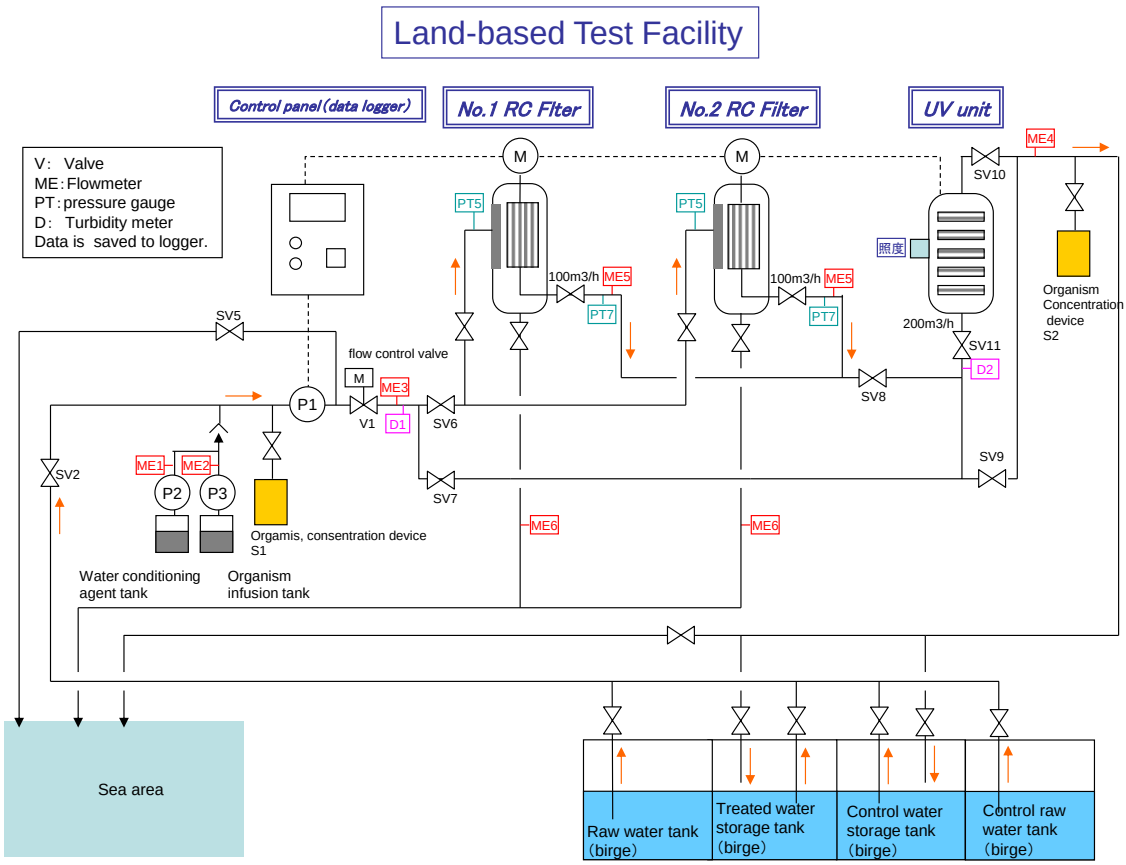

Figure 1 Schematic view of land-based test facility

3. Test water

Conduct the land-based test in a total of 10 test cycles including 5 test cycles using test water with a salinity of over 32 psu (seawater) and 5 test cycles using test water with a salinity of 3 to 32 psu (brackish water), where the salinity difference between seawater and brackish water should be at least 10 psu.

Prepare the test water using original water at the test site as follows:

- Seawater
  Measure the salinity of the original water in the original water tank for treatment group and adjust it over 32 psu by adding high salinity ocean water.
- Brackish water
  Measure the salinity of the original water in the original water tank for treatment group and adjust it less than 22 psu by adding fresh water around the test site.

Add the following water conditioners in the water conditioner tank to meet the water quality requirement. The dosage is changed depending on the original water quality :

- DOC : Glanilated sugar, Nissin Sugar Manufacturing Co., Ltd. (seawater: 2.2 kg/200 m^3; brackish water: 14.0 kg/200 m^3)
- POC : Cornstarch Y-3P, Japan Cornstarch Co., Ltd (seawater: 2.2 kg/200 m^3; brackish water: 7.0 kg/200 m^3)
- TSS : Quartz sand No.7, Kitanihon Sangyo Co., Ltd (seawater: none; brackish water: 14.0 kg/200 m^3)

Add the following organisms in the organism tank to meet the organism requirement:

- Greater than or equal to 50 μm (L size group): *Brachionus plicatilis*
  Add it if the density is below 10^5 individuals/m^3 according to the water inspection before each test cycle, because it was verified that the original water contains over 10^5 individuals/m^3 almost at any time.
- Greater than or equal to 10 μm and less than 50 μm (S size group): *Tetraselmis* sp.
  Add 30 10L-cans including 1.5×10^6 individuals/ml per 200 m^3 in the sea and brackish water treatment groups.
  Adjust the dosage by verifying the density and the mobility of organisms in cans.
- Heterotrophic bacteria
  Do not add it, because it was verified that the original water does not contain over 10^4 cfu/ml at any time.

Table 1 Salinity of land-based test water quality requirement

	Salinity		
	>32 PSU	**3-32 PSU**	**<3 PSU**
Dissolved organic carbon (DOC)	>1 mg/l	>5 mg/l	>5 mg/l
Particulate organic carbon (POC)	>1 mg/l	>5 mg/l	>5 mg/l
Total suspended solids (TSS)	>1 mg/l	> 50mg/l	>50 mg/l

4. Test procedure

Each test cycle includes the following procedure:

- Take up ballast water by the pump;
- Treat ballast water by the system;
- Store Ballast water in the simulated ballast tank on the test barge for at least 5 days; and
- Discharge ballast water by the pump.

Table 2 shows the detailed test procedure of each test cycle and the Figure 2 shows the test flow.

Table 2-1 Test procedure during ballasting

No.	Test Procedure	Component
0-1	Prepare test water.	Water conditioner tank Organism tank
0-2	Prepare sampling unit and sample vessel (see Section II QUALITY ASSURANCE PROJECT PLAN (QAPP), Paragraph 2.1 and 2.2 of QUALITY MANAGEMENT PLAN (QMP) AND QUALITY ASSURANCE PROJECT PLAN (QAPP) OF THE APPROVAL TESTING PROCESS).	Sampling unit SP1 and SP2
1	Arrange personnel.	
2	Check the start-up of the filter unit.	Filter unit 1 and 2 Control panel
3	Check the start-up of the UV unit.	Control panel
4	Set the UV dose at 100 mJ/cm^2.	Control panel
5	Establish the seawater line from the original water tank for treatment group to the treated water storage tank.	Valve
6	Start the ballast pump P1 (Set the read out value of the flow meter at 210 m^3/h to ensure the flow rate of 200 m^3/h considering the measurement error).	Control panel
7	Add water conditioners and organisms.	Pump P2 and P3
8	Conduct sampling of the ballast water before treatment and immediately after treatment (at the beginning, middle and end).	Sampling unit SP1 and SP2
9	Stop the UV unit.	Control panel
10	Stop the filter unit.	Control panel
11	Stop the ballast pump P1.	Control panel
12	Establish the seawater line from the original water tank for control group to the storage tank for control group.	Valve
13	Start the ballast pump P1 (Set the read out value of the flow meter at 210 m^3/h to ensure the flow rate of 200 m^3/h considering the measurement error).	Control panel
14	Add water conditioners and organisms.	Pump P2 and P3
15	Conduct sampling of the control water (at the beginning, middle and end).	Sampling unit SP1
16	Stop the ballast pump P1.	Control panel
17	Clean up the test facility and the test barge.	

Table 2-2 Test procedure during de-ballasting

No.	Test Procedure	Component
0-1	Prepare sampling unit and sample vessel (see Section II QUALITY ASSURANCE PROJECT PLAN (QAPP), Paragraph 2.1 and 2.2 of QUALITY MANAGEMENT PLAN (QMP) AND QUALITY ASSURANCE PROJECT PLAN (QAPP) OF THE APPROVAL TESTING PROCESS).	Sampling unit SP1 and SP2
1	Arrange personnel.	
2	Check the start-up of the UV unit.	Control panel
3	Set the UV dose at 100 mJ/cm^2.	Control panel
4	Establish the seawater line from the treated water tank to the UV unit and from the UV unit overboard.	Valve
5	Start the ballast pump P1 (Set the read out value of the flow meter at 210 m^3/h to ensure the flow rate of 200 m^3/h considering the measurement error).	Control panel
6	Conduct sampling of the treated water (at the beginning, middle and end).	Sampling unit SP2
7	Stop the UV unit.	Control panel
8	Stop the ballast pump P1.	Control panel
9	Establish the seawater line from the storage tank for control group to the sampling unit SP2 and form the sampling unit SP2 overboard.	Valve
10	Start the ballast pump P1 (Set the read out value of the flow meter at 210 m^3/h to ensure the flow rate of 200 m^3/h considering the measurement error).	Control panel
11	Conduct sampling of the control water (at the beginning, middle and end).	Sampling unit SP2
12	Stop the ballast pump P1.	Control panel
13	Clean up the test facility and the test barge.	

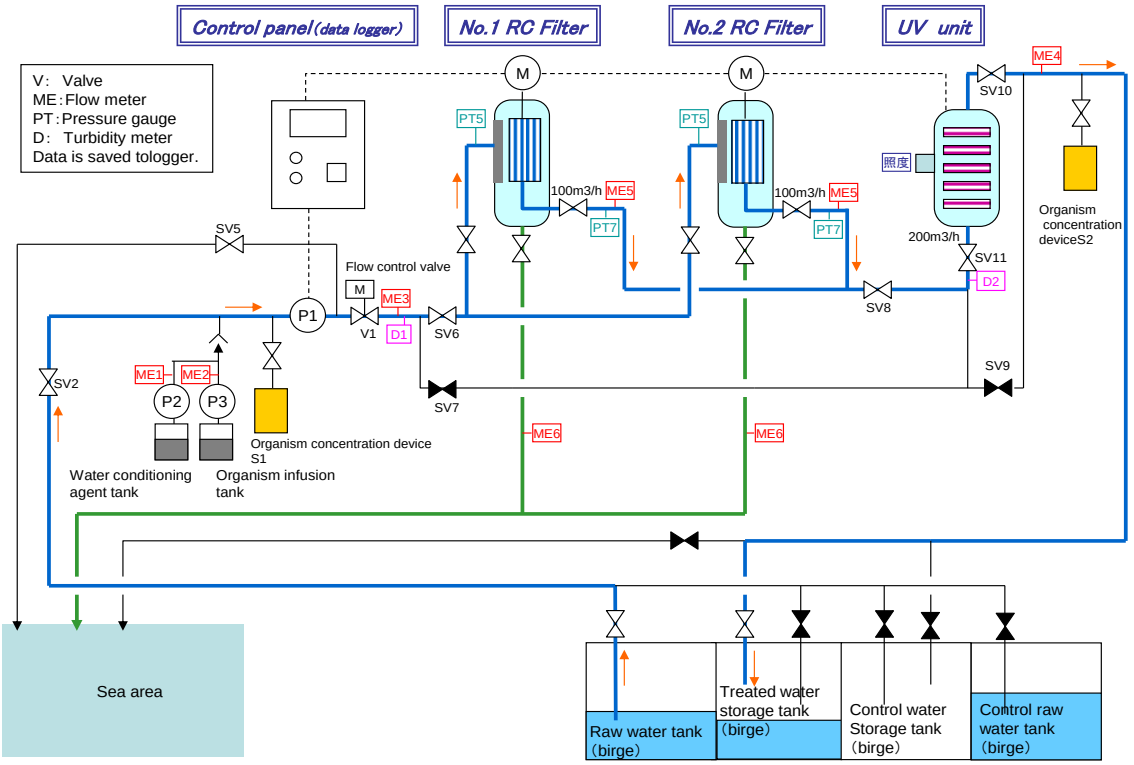

Figure 2-1 Test flow (treated water during ballasting)

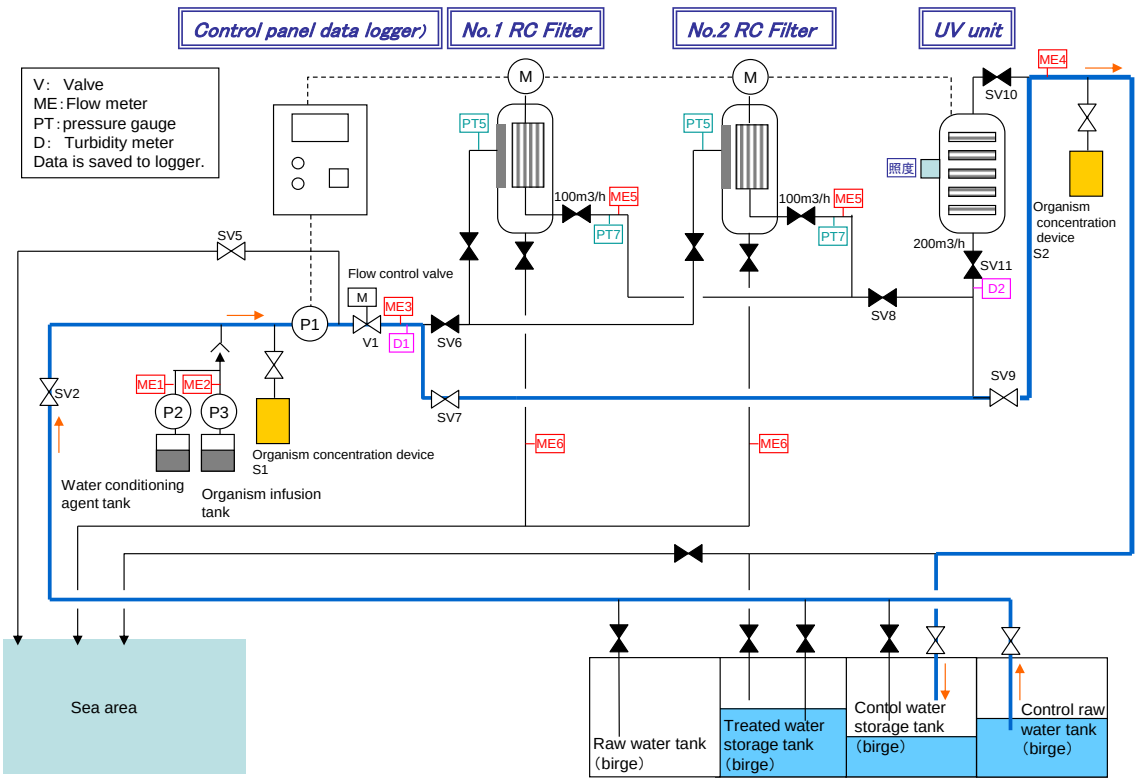

Figure 2-2 Test flow (control water during ballasting)

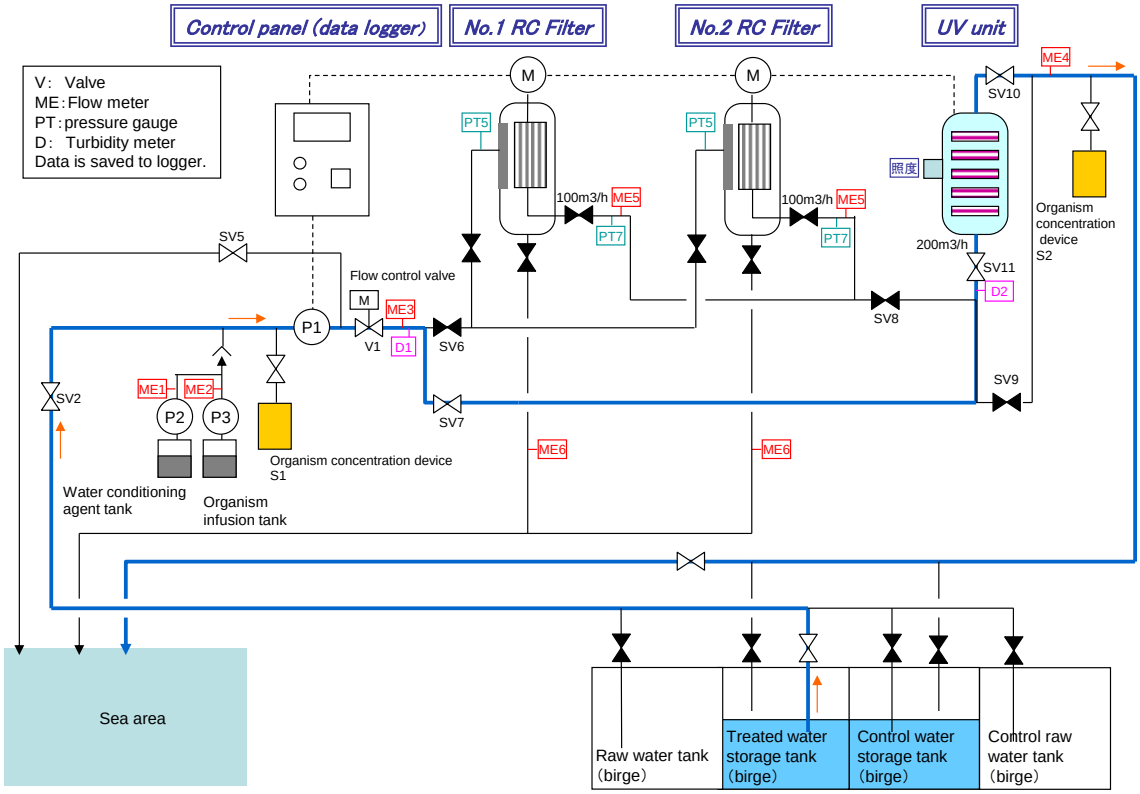

Figure 2-3 Test flow (treated water during de-ballasting)

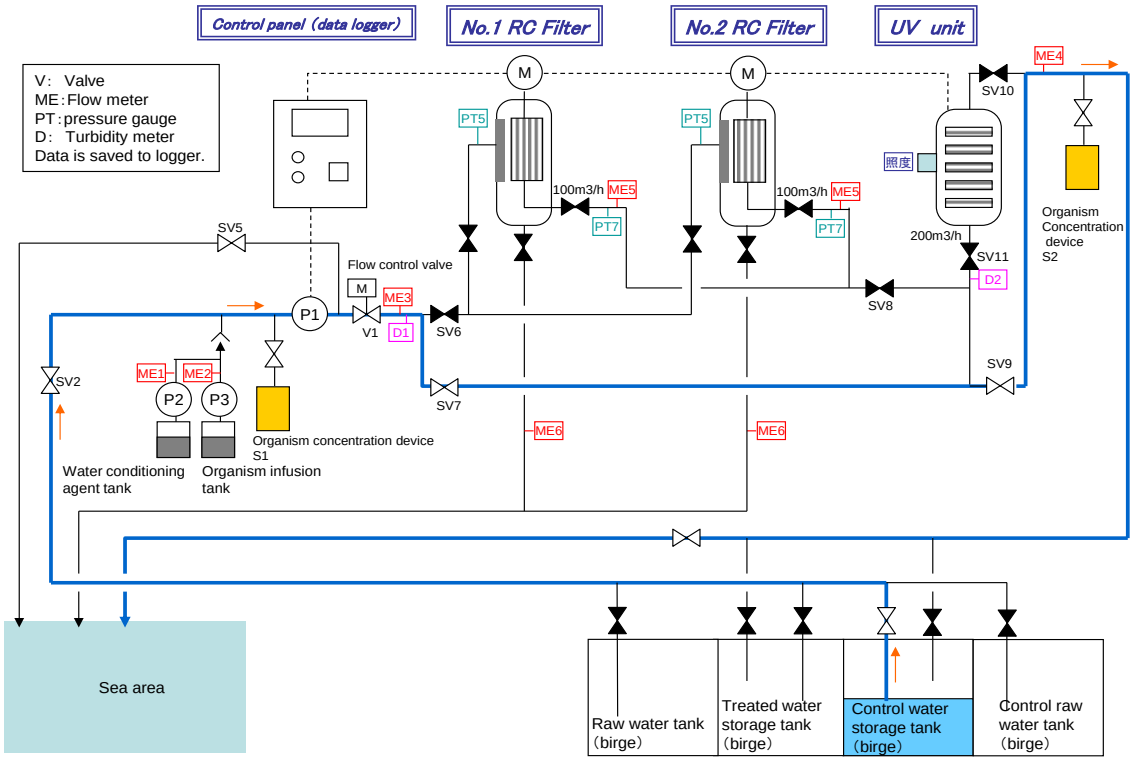

Figure 2-4 Test flow (control water during de-ballasting)

5. Sampling and analysis methods

5.1 Sampling method

Section II QUALITY ASSURANCE PROJECT PLAN (QAPP), Paragraph 3. of QUALITY MANAGEMENT PLAN (QMP) AND QUALITY ASSURANCE PROJECT PLAN (QAPP) OF THE APPROVAL TESTING PROCESS.

(1) Sampling unit

In accordance with Section II QUALITY ASSURANCE PROJECT PLAN (QAPP), Paragraph 2.1 of QUALITY MANAGEMENT PLAN (QMP) AND QUALITY ASSURANCE PROJECT PLAN (QAPP) OF THE APPROVAL TESTING PROCESS that is designed to provide the same flow rate at the sampling as that in the ballast line (isokinetic sampling).

(2) Sampling period and frequency

1) Control water

- During ballasting

  3 times at the beginning, middle and end of ballasting.

- During de-ballasting

  3 times at the beginning, middle and end of de-ballasting.

2) Treated water

- During ballasting

  3 times at the beginning, middle and end of ballasting immediately before the ballast water is supplied into the system and 3 times at the beginning, middle and end of ballasting immediately after treatment.

- During de-ballasting

  3 times at the beginning, middle and end of de-ballasting

(3) Sampling item and quantity

1) Viable organisms greater than or equal to 50 μm (L size group): over 1 m^3

   Conduct sampling after concentrating by the sampling unit.

2) Viable organisms greater than or equal to 10 μm and less than 50 μm (S size group): over 1 L (10 L for treated water).

3) Bacteria: 3 L

4) Water quality (pH, salinity, water temperature, dissolved oxygen, particulate organic carbon (POC), total suspended solids (TSS) and turbidity (NTU)): over 5 L for pH, salinity, water temperature and dissolved oxygen, 250 ml for POC and 1 L for TSS.

5.2 Analysis method

Section II QUALITY ASSURANCE PROJECT PLAN (QAPP), Paragraph 4. of QUALITY MANAGEMENT PLAN (QMP) AND QUALITY ASSURANCE PROJECT PLAN (QAPP) OF THE APPROVAL TESTING PROCESS.

Conduct analysis within 6 hours after sampling or set samples in a properly analyzable condition.

5.3 Recorded item

① Flow rates at the treatment and during ballasting into the control water tank
② Flow rates of treated and control water during de-ballasting
③ Water volumes in the treated water storage tank and the control water storage tank
④ Capacities of the treated water storage tank and the control water storage tank
⑤ UV dose
⑥ Pressures before and after the UV unit
⑦ Power consumption of the system
⑧ Water volume supplied into the sampling unit at the sampling
⑨ Backwashing condition of the filter unit
⑩ Leakage
⑪ Other necessary items

6. Schedule

Test cycle	Date of ballasting	Date of de-ballasting
Seawater 1	April 4, 2011	April 16, 2011
Seawater 2	April 21, 2011	April 26, 2011
Seawater 3	October 4, 2011	October 9, 2011
Seawater 4	October 21, 2011	October 26, 2011
Seawater 1	October 24, 2011	October 29, 2011
Brackish water 1	April 4, 2011	April 9, 2011
Brackish water 1	April 14, 2011	April 19, 2011
Brackish water 1	April 24, 2011	April 29, 2011
Brackish water 1	October 11, 2011	October 16, 2011
Brackish water 1	October 14, 2011	October 19, 2011